

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:  
20.02.2002 Bulletin 2002/08

(51) Int Cl.7: H04B 1/10, H04B 1/12,  
H04L 27/26

(21) Application number: 01306712.9

(22) Date of filing: 06.08.2001

(84) Designated Contracting States:  
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU  
MC NL PT SE TR  
Designated Extension States:  
AL LT LV MK RO SI

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(30) Priority: 16.08.2000 GB 0020071

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(54) COFDM tuner with impulse noise reduction

(57) A tuner for digital terrestrial television (DVB-T, employing COFDM modulation), has an input section (2-15) which supplies a sample intermediate signal, for example at zero intermediate frequency and digitised by an ADC (12), corresponding to a desired reception channel corrupted by interference such as impulsive noise interference. A threshold generator (16) gener-

ates a threshold which is larger than a moving average of the amplitudes of consecutive samples and a comparator (17) compares the amplitudes of the samples with the threshold. If a sample amplitude exceeds the threshold, a corrector (18) sets to zero the sample before processing by a fast Fourier transform (19). The threshold generator (16) excludes samples which have been set to zero from the moving average.

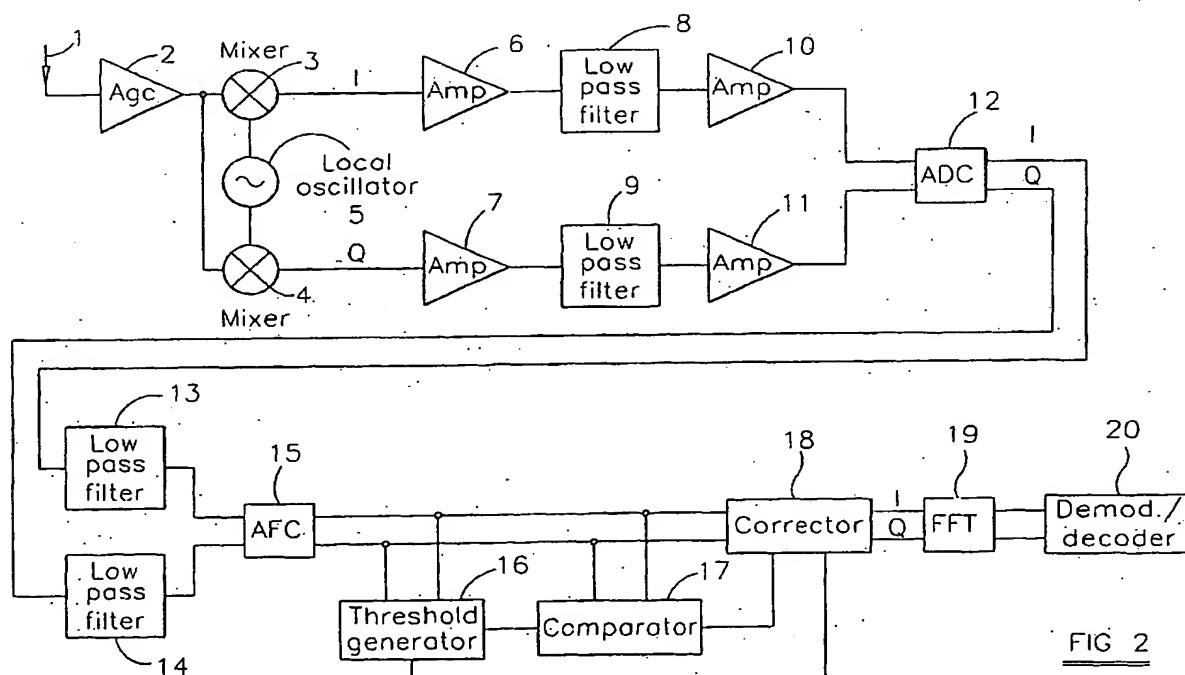


FIG 2

## Description

[0001] The present invention relates to a tuner. Such a tuner may, for example, be used for receiving television signals and may form part of a set-top box, a television receiver or a video cassette recorder.

[0002] The DVB-T (Digital Video Broadcasting - Terrestrial) standard for DTT (Digital Terrestrial Television) employs Coded Orthogonal Frequency Division Multiplexing (COFDM) as the modulation scheme for transmission of the digital bit-stream. Implementation of the modulators and demodulators in this system is accomplished using the Inverse Fast Fourier Transform (IFFT) algorithm to generate the time domain signal from the complex frequency domain representation at the transmitter and the Fast Fourier Transform (FFT) to recover the complex constellation of data points at the receiver. These operations apply to separate COFDM "symbols" of a length in time equal to the reciprocal of the individual carrier spacing. Thus, each symbol corresponds to a constellation of points in the complex plane, i.e. each carrier has fixed amplitude and phase for the duration of a symbol.

[0003] Impulse noise may occur via switching transients of nearby appliances, such as fridges and power tools. An important marketing point of DTT is the ease of installation, allowing the consumer to set the system up alone. This unfortunately makes it likely that, in many cases, a far from ideal installation will be achieved, increasing the likelihood of poor interference protection.

[0004] If impulse noise occurs superimposed on the received radio frequency (RF) signal at the antenna, this will appear at the input to the FFT as the impulse response of the intervening tuner/receiver components. The impulse energy in band will typically have a wide band sinc-type envelope and will flood the received data spectrum, causing many errors in one transmitted COFDM symbol. Once the spectrum after the FFT is corrupted, correction is not possible and it is the nature of the COFDM modulation scheme that makes it vulnerable to impulse noise. However, digitisation of the COFDM signal at intermediate frequency (IF) by an analogue/digital converter (ADC) tends to suppress impulse noise in conventional tuner designs. These will suppress unwanted channels in the analogue domain prior to the ADC. Hence the whole dynamic range of the ADC will be filled with the unwanted channel signal. High level impulsive noise will be clipped at the ADC, assuming that the receiver AGC loop does not "capture" the impulse level and adjust the gain. This is very unlikely as the impulse will by definition be a short pulse, of the order of nanoseconds in length.

[0005] There is a desire to increase processing in the Digital domain, thus shifting the tight specifications to the ADC. In such systems, it is probable that any adjacent channel unwanted energy will be digitised by the ADC along with the desired channel. In this case, if the adjacent channel is at a higher level (for example in the

UK where it may be +35dB relative to the wanted DVB-T channel), only part of the ADC dynamic range will be occupied by the wanted signal, allowing a much higher level impulse through to the FFT. This will in turn translate to much higher level interference across the wanted spectrum of COFDM carriers, causing extremely high error rates for the symbol in which the impulse occurred.

[0006] Figure 1 of the accompanying drawings shows typical conditions for such a direct tuner system receiving a wanted signal at 35dB below an adjacent channel (a PAL Analogue TV channel). This drawing illustrates the three components of the signal at the ADC input, namely the adjacent channel PAL signal, the desired COFDM signal (illustrated in "white" superimposed on the PAL signal) and the noise impulse. If an impulse occurs at an amplitude +50dB relative to the PAL peak amplitude and is then clipped to that same amplitude, the received complex constellation after FFT will show a bit error rate (BER) prior to any Viterbi decoding of the order of 40% (for Quasi Error free transmission, this value should be less than 1%). Such an increase in BER will not cause problems with receiver lock, as long as the impulse occurs infrequently. However, it is possible that visible distortion will occur on the picture, depending on the programme being viewed and the MPEG-2 decoder chip. If impulsive noise corrupts consecutive symbols, the problem will become more severe.

[0007] EP 0 597 525 discloses a noise suppression arrangement for frequency modulation (FM) receivers. A noise detection arrangement passes signals above a threshold, which signals are assumed to be noise, to a holding circuit which holds the immediately preceding signal level to perform a crude interpolation to replace the noise.

[0008] Similarly, US 5 261 004 discloses a noise blanking arrangement in which the signal level is held when noise is detected. In order to detect noise, various signals are compared with filtered examples of the signal.

[0009] EP 0 651 521 discloses a noise detection arrangement for use in radio telephony. Noise is detected by means of filtering with two different time constants.

[0010] According to a first aspect of the invention, there is provided a tuner comprising an input section for converting a radio frequency signal to a sampled intermediate signal, a threshold generator for generating a threshold as a function of an average of the amplitudes of a plurality of samples of the intermediate signal, a comparator for comparing the amplitude of each of the samples with the threshold, and a corrector responsive to the comparator for setting to zero each of the samples whose amplitude is greater than the threshold, the threshold generator excluding from the average any sample whose amplitude exceeds the threshold.

[0011] The corrector may be arranged to set to zero n consecutive samples after each sample whose amplitude is greater than the threshold, where n is a positive integer, n may be a function of the impulse response of

the input section.

**[0012]** The corrector may be arranged to set to zero  $m$  consecutive samples before each sample whose amplitude is greater than the threshold, where  $m$  is a positive integer.  $m$  may be a function of the impulse response of the input section.

**[0013]** The average may be a moving average.

**[0014]** The threshold may be greater than the product of the average and the peak-to-average ratio of the intermediate signal.

**[0015]** The threshold may be greater than three times the average. The threshold may be substantially equal to 5.3 times the average.

**[0016]** The samples may have a sample rate of 9.143MHz.  $n$  may be greater than 1 and less than 5. The moving average may be over a window of substantially 1000 consecutive samples.

**[0017]** The input section may comprise a zero intermediate frequency converter.

**[0018]** The input section may supply the samples at in-phase and quadrature outputs.

**[0019]** The input section may comprise an analogue/digital converter for forming the samples as digital samples.

**[0020]** The tuner may be provided for receiving COFDM signals.

**[0021]** The tuner may comprise a fast Fourier transformer for processing samples from the corrector.

**[0022]** The tuner may be provided for receiving television signals.

**[0023]** According to further aspects of the invention, there are provided a set-top box, a television receiver and a television signal recorder, each comprising a tuner according to the first aspect of the invention.

**[0024]** It is thus possible to provide a tuner whose performance is substantially improved under impulsive noise conditions. In the case of digital television signals, bit error rate performance can be substantially improved so that picture interference is reduced. These techniques are particularly useful for modulation schemes which make use of a fast Fourier transform algorithm in the tuner, for example to extract the complex value of each carrier in a COFDM scheme.

**[0025]** The invention will be further described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a waveform diagram illustrating an impulse-corrupted digital television signal and a high level adjacent channel PAL analogue signal;

Figure 2 is a block circuit and functional diagram illustrating a tuner constituting an embodiment of the invention; and

Figure 3 illustrates diagrammatically the effect of impulsive noise interference and the improvement in performance which may be achieved by the tuner

of Figure 2.

**[0026]** The COFDM television tuner shown in Figure 2 is connected to an aerial input 1 and comprises an input automatic gain control (AGC) amplifier 2 whose output is connected to mixers 3 and 4. The mixers 3 and 4 form part of a zero intermediate frequency (ZIF) frequency converter for converting the input signals directly to baseband signals. A local oscillator 5 supplies local oscillator signals to the mixers 3 and 4 which are in phase quadrature with respect to each other so that the mixer 3 produces an in-phase signal I and the mixer 4 produces a quadrature phase signal Q. The outputs of the mixers 3 and 4 are supplied via buffer amplifiers 6 and 7, respectively, to low pass filters 8 and 9, respectively, which attenuate or eliminate energy outside the zero intermediate frequency bandwidth. The outputs of the filters 8 and 9 are supplied via further buffer amplifiers 10 and 11, respectively, to an analogue/digital converter (ADC) 12.

**[0027]** The parts 2 to 11 of the tuner represent an analogue section whose quadrature output signals are converted by the ADC 12 to the digital domain. The remaining parts of the tuner operate in the digital domain and are illustrated as functional blocks in Figure 2 although they would normally be embodied by dedicated digital hardware or possibly by a programmable data processor under software control.

**[0028]** The outputs of the ADC 12 are supplied via digital low pass filters 13 and 14 to an automatic frequency control (AFC) circuit 15, which centres the signals exactly around 0Hz.

**[0029]** The digitised samples of the I and Q signals formed by the ADC 12, filtered by the filters 13 and 14 and centred on 0Hz by the circuit 15 are supplied to the inputs of a threshold generator 16, a comparator 17 and a corrector 18. In a typical example of the tuner shown in Figure 2, the ADC 12 samples the incoming signals at a sample rate of 9.143MHz. The threshold generator 16 forms a moving average of a number of consecutive samples of each of the I and Q signals. In the specific example mentioned above, the moving window covers about 1000 consecutive samples.

**[0030]** In order to generate a threshold which is capable of discriminating impulsive noise signals, the threshold generator 16 makes use of the known peak-to-mean ratio of COFDM signals, which is about 9.5 decibels (dB) (a ratio of about 3:1). In order to avoid false triggering, the threshold generator 16 sets the threshold higher than this, for example by 3dB or even by as much as 5dB, so that the threshold supplied to the comparator 17 by the generator 16 is, for example, substantially equal to 5.3 times the moving window average of the amplitudes of the samples.

**[0031]** The comparator 17 compares each of the I and Q samples with the threshold and signals the corrector 18 whenever the amplitude of a sample exceeds the current value of the threshold. In response to such signal-

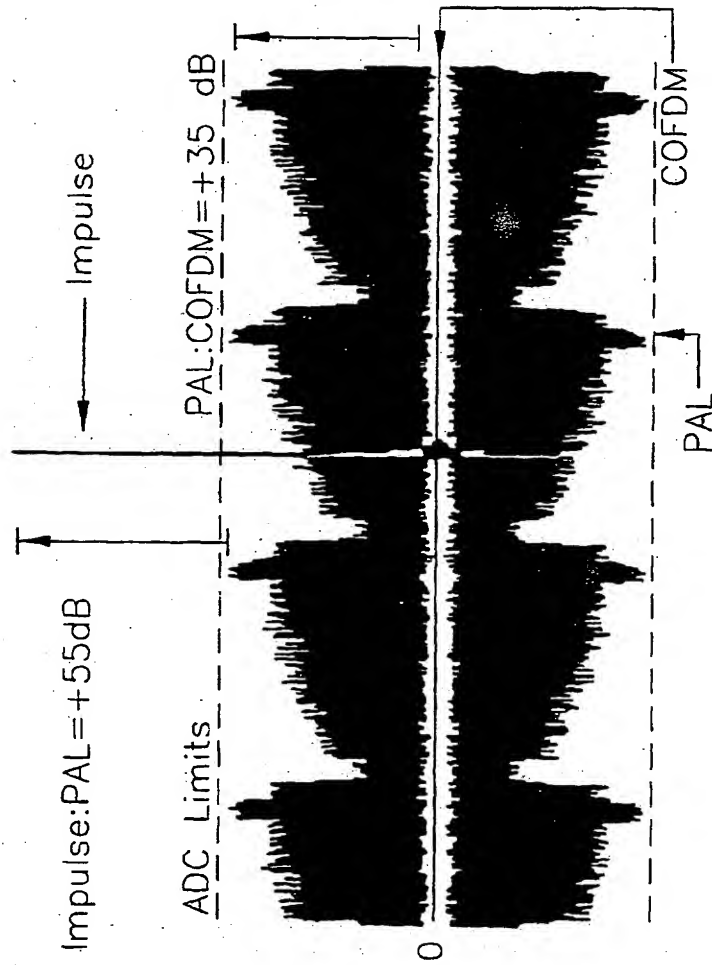


FIG 1

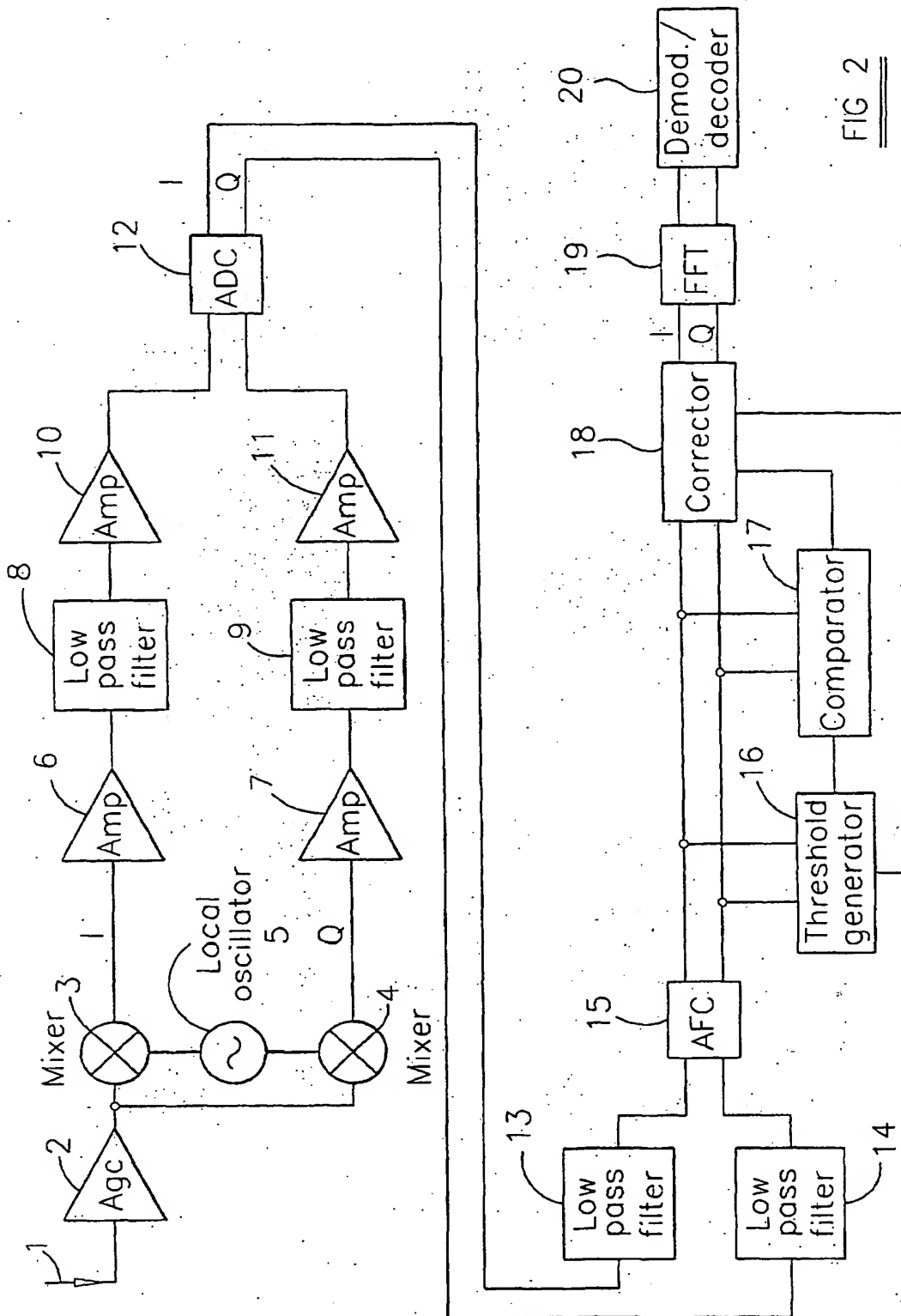


FIG 2

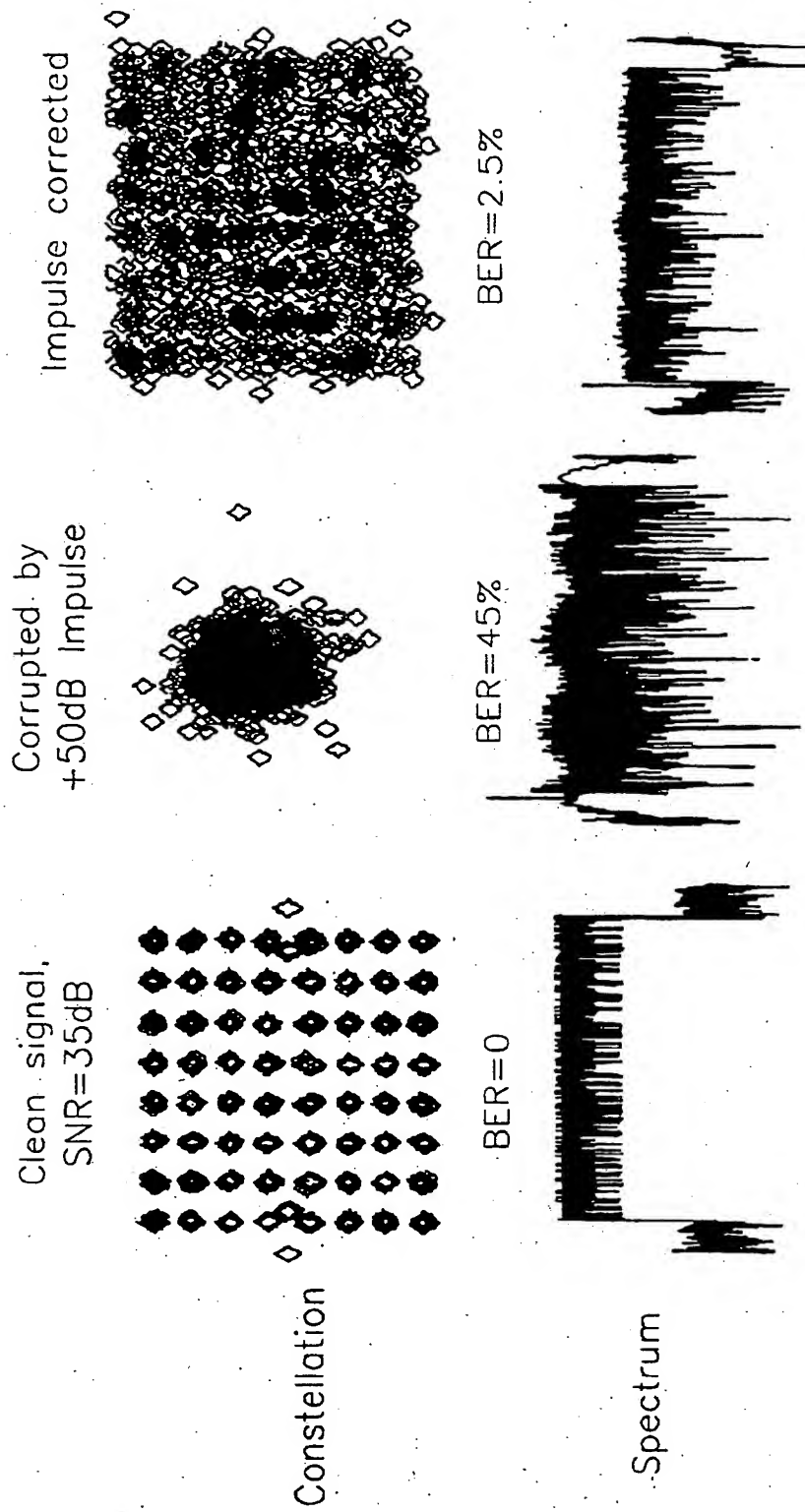


FIG. 3

(19)



Europäisches Patentamt

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(11)

EP 1 180 851 A3

(12)

## EUROPEAN PATENT APPLICATION

(88) Date of publication A3:  
27.02.2002 Bulletin 2002/09

(51) Int Cl.7: H04B 1/10, H04B 1/12,  
H04L 27/26

(43) Date of publication A2:  
20.02.2002 Bulletin 2002/08

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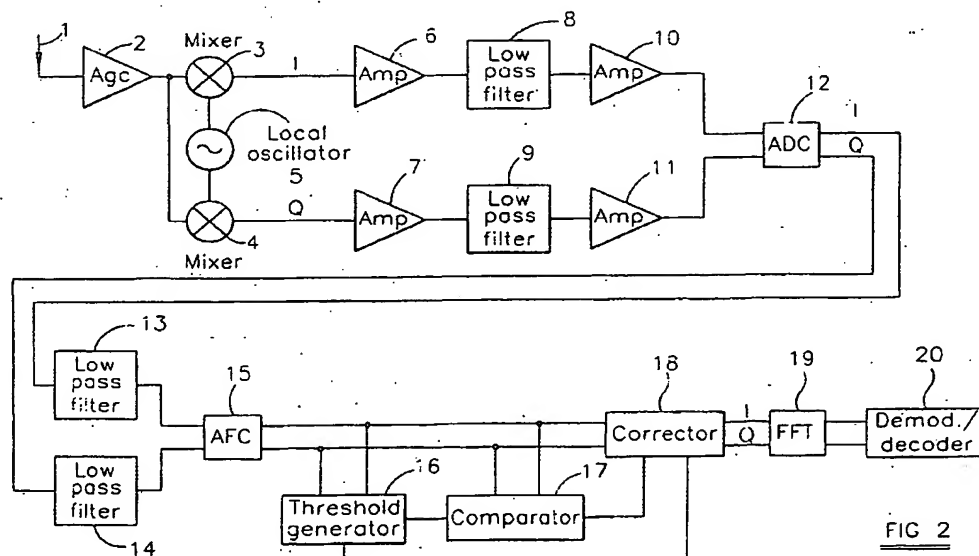


FIG 2

EP 1 180 851 A3



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# EUROPEAN SEARCH REPORT

Application Number  
EP 01 30 6712

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	EP 0 930 719 A (MITSUBISHI ELECTRIC CORP) 21 July 1999 (1999-07-21) * column 4, line 27 - line 30 * * paragraph [0023] * * column 4, line 52 - line 54 * * paragraphs [0025], [0026] * * column 5, line 29 - line 30 * * paragraphs [0033], [0034] * * paragraph [0038] * * column 10, line 28 - line 41 * * figures 1,3,6,14 *	1,4-6,8, 9,12-14	H04B1/10 H04B1/12 H04L27/26
A	---	2,3	
A	US 4 736 163 A (BERKHOUT PETRUS J ET AL) 5 April 1988 (1988-04-05) * abstract *	1,4-6,9	
			<b>TECHNICAL FIELDS SEARCHED (Int.Cl.7)</b>  H04B H04L
<p><del>The present search report has been drawn up for all claims</del></p>			
Place of search <b>BERLIN</b>		Date of completion of the search <b>1 October 2001</b>	Examiner <b>Farese, L</b>
<b>CATEGORY OF CITED DOCUMENTS</b> X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

EPO FORM 1503 03/92 (P4/Cut)





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Application Number

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### CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

### LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1-6, 8, 9, 12-14



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Office

**LACK OF UNITY OF INVENTION  
SHEET B**

Application Number

EP 01 30 6712

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. Claims: 1-6, 8, 9, 12-14

impulse noise cancelling

2. Claim : 7

demodulation

3. Claims: 10-11

frequency domain base-band signal processing

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 01 30 6712

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on  
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01-10-2001

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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

